Doctor of Physical Therapy Program Case Reports

2018

Differential Diagnosis of an Adolescent Swimmer with Chronic Shoulder Pain and Cervical Spine Involvement: A Case Study

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Abstract

Background & Purpose: Shoulder pain is the most common orthopedic issue affecting swimmers.[19] Swimming requires adequate cervical motion in order to breathe and high muscular forces at extreme ranges of shoulder motion, as majority of propulsive forces come from the upper extremities. Differential diagnosis in swimmers can be difficult due to similar presentations and interconnecting diagnoses, but remains essential to provide effective, efficient care. **Case Description:** A 14 year old female competitive swimmer with chronic right shoulder pain of one year in duration was treated in physical therapy after undergoing two prior unsuccessful episodes of physical therapy and one bout of chiropractic care. **Differential Diagnosis:** The top three diagnoses were cervical spine weakness and hypermobility, subacromial impingement, and scapular dyskinesia, respectively. **Discussion:** Abundant research discussing differential diagnosis in swimmers with shoulder pain is available, yet majority do not mention the cervical spine as a potential pain generator. Our patient had complete resolution of her shoulder pain following eight visits that focused on cervical spine strengthening and endurance without any periscapular or rotator cuff exercises. Therefore, this case provides an example of cervical spine involvement in a patient with chronic shoulder pain and evidence for the importance of including cervical spine in the differential diagnosis of swimmers.

Background:

The shoulder complex is one of the most interconnected and complicated articulations of the body requiring patients with shoulder pain be thoroughly evaluated. The shoulder complex is made up of 4 joints including the sternoclavicular (SC) joint, acromioclavicular (AC) joint, glenohumeral (GH) joint, and scapulothoracic (ST) joint. Patients presenting with shoulder pain could have many different local structures contributing to pain such as the glenoid labrum, rotator cuff muscles and their respective tendons, or surrounding bursa. Pain in the shoulder can also be referred pain from the neck or other internal organs such as the heart. Therefore, differential diagnosis with shoulder patients is critical to be able to provide effective treatment and facilitate healing.

Shoulder pain is a common orthopedic issue for the general population, but prevalence of shoulder pain in swimming athletes is even higher. It has been reported that shoulder pain can affect 40-91% of swimming athletes which makes it the most common orthopedic issue in this population.[19] Shoulder pain in swimming athletes has been so common that in 1974, Kennedy and Hawkins coined the term "swimmer's shoulder" to describe pain and dysfunction caused by repeated shoulder impingement in competitive swimmers.[16,19] Even though this is not a formal diagnosis, it provides evidence for the high prevalence of shoulder pain in swimmers.

Swimming is a unique exercise because it requires up to 90% of the driving and propulsive forces to originate from the upper extremities. [19] These high muscular forces typically occur between neutral and extreme ranges of shoulder motion. Further, elite swimmers often have highly repetitive motions with 4,000-5,000 shoulder revolutions per day and swimming distance from 3.6-9 miles per practice.[5,19,13] This highly repetitive activity may predispose athletes to a variety of orthopedic issues.

Another unique aspect of swimming is the extra effort and coordination it takes to breathe. Many swimming strokes require a prone position, with the most common swimming stroke being the front crawl, also known as the freestyle. This stroke requires sufficient neck range of motion and strength in order to rotate the head while breathing to the side. Unilateral breathing, or breathing to the same side, can cause asymmetries in coordination, strength, and range of motion of the upper extremity and neck. Chollet et al. found that arm coordination asymmetries can be reduced or prevented by using balanced breathing patterns. [3]

With the unique aspects of swimming and the complexity of the shoulder, differential diagnosis for swimming athletes can be difficult. Wes et al. reported differential diagnosis in this patient population should include "Hyperlaxity, scapular dyskinesis, subacrominal impingement, labral damage, os acromiale, suprascapular nerve entrapment, and glenohumeral rotational imbalances". [19] Clinicians also need to be aware of other medical issues such as spinal cord abnormalities, congenital conditions, brachial plexus and vascular components, tumors, arthritis, infections, and instability according to William McMaster, MD.[11] However, cervical spine mechanisms were not specifically identified by either author.

With the multitude of possible diagnoses in swimmers, clinicians should understand the various mechanisms and common features of each diagnosis to aid in clinical decision making when determining the plan of care. Therefore, further description of commonly researched orthopedic shoulder pathologies in swimmers are described in Table 1.

Table 1. Common Shoulder Conditions in Swimmers.	
Condition	Findings
Hyperlaxity	Hyperlaxity is found in about 20% of competitive swimmers as full to excessive range of motion of the shoulder is necessary for propulsion and speed. It has been found that stroke length is considered the most discriminative parameter of velocity, which can be achieved best by optimal shoulder range of motion.[1] However, hyperlaxity leads to instability and increased translation of the humeral head which can be damaging to the surrounding structures and result in inflammation, pain, and scarring. Loss of dynamic control by the rotator cuff muscles and increased joint laxity often presents as a dropped elbow during the recovery phase of swimming and a lack of body roll.[19]
Scapular dyskinesia	Scapular dyskinesia may be due to a multitude of factors such as weak periscapular stabilizers, overactive pectoralis major, tight pectoralis minor and short head of bicep brachii, or abnormal upper trapezius activation. All of these factors can prevent normal scapular motion and result in poor swimming mechanics. One study found up to 82% of pain-free swimmers demonstrated irregular scapular motion during a training session.[19] Scapular dyskinesia has also been found more prevalent as muscles fatigue and therefore, swimmers are at higher risk for injury after long periods of activity.[8]
Subacromial impingement and bursitis	Impingement has been found to occur during 24.8% of the free style stroke, especially during the point of hand entry.[7] The subacromial space holds many important structures such as supraspinatus tendon, long head of the biceps brachii, and subacromial bursa. Decreased space places these structures at higher risk for injury which can occur due to abnormal muscle activation or tension, scapular dyskinesia, repetitive overhead motions, and the presence of inflammation. Wes et al. found the leading cause of shoulder pain in swimmers was a result of supraspinatus tendinopathy from subacromial impingement.[19] Subcromial bursitis occurs when the bursa within the subacromial space becomes inflamed and painful due to repetitive trauma or friction from surrounding structures. This can lead to a continual cycle of injury as neighboring structures, such as the supraspinatus and long head of the biceps brachii, are now at increased risk of pathology.
Labral damage	Swimming athletes are at a higher risk for labral damage due to a combination of repetitive adduction and internal rotation of the humerus and increased capsular laxity. With increased translation of the humeral head in lax shoulder joints, the labrum is at risk of becoming frayed or torn. If injury to the labrum does occur, it can result in pain or sensations of catching or clicking as disconnected portions may start to interfere with normal joint mechanics.
Suprascapular nerve entrapment	The suprascapular nerve arises from the upper trunk of the brachial plexus with roots from C5-C6. It travels along the omohyoid muscle, passes deep to the upper trapezius, and continues to the superior edge of the scapula and then through the

	suprascapular notch.[10] This nerve supplies motor innervation to the supraspinatus and infraspinatus muscles and sensory to the superior, posterior glenohumeral capsule. A traction type neuropathy can occur as swimmers fatigue due to a dropped elbow, reduced body roll, and scapular winging during the front stroke.[19] Muscular weakness of the supraspinatus and infraspinatus would increase probability of this diagnosis as the suprascapular nerve provides motor innervation to these muscles, although electromyography (EMG) is the definitive test.
Bicipital tendinitis	The long head of the bicep originates from the supraglenoid tubercle of the scapula and inserts into the bicipital aponeurosis and radial tuberosity. The long head of the biceps runs through the intertubercular groove of the humerus and deep to the acromion to its attachment point of the supraglenoid tubercle and superior portion of the labrum. Due to its location, it can assist in anterior stability of the glenohumeral joint. With increased laxity common in swimmers, the long head of the biceps can become irritated as the anterior portion of the humeral head approximates with the posterior side of the biceps brachii muscle and tendon.

Although it is beneficial and necessary to understand the more common shoulder pathologies in swimmers, the differential diagnosis should also consider the cervical spine. One study examined neck and shoulder pain patients presenting to a neck or shoulder surgeon clinic respectively. They found that approximately 1 in every 25 patients seen for presumed neck or shoulder issues may exhibited cross over or coexistent pathologies. That is, pathology or source of the pain may be misinterpreted as pain originating from a source in the neck when it is in fact coming from a source in the shoulder and vice versa.[15] This suggests, that while not common, roughly 4% of patients presenting with shoulder pain may in fact have a cervical spine condition.

The subject of this case is an adolescent female swimmer, age 14, with chronic shoulder pain. Differential diagnosis may be further challenged in this population due to the attitudes, beliefs, and motivations of adolescent advanced swimmers. In one study, 72% of advanced swimmers ages 13-18 reported using pain medication in the past year to manage shoulder pain and 47% reported using pain medication once or more per week in order to continue practicing.[13] Further, they found 85% of high school aged swimmers suffered mild shoulder pain, 61% suffered moderate, and 21% suffered severe shoulder pain within the last year, indicating this is a highly prevalent condition. Despite this prevalence, only 14% of the swimmers had sought advice from a healthcare provider.[13] This suggests that this population believes shoulder pain is either not associated with injury or is a normal consequence of participating in a high level sport, which may amplify their risk for pathology and result in more severe injuries. This also is indicative of the difficulty of getting these patients to seek treatment for their shoulder pain as well as continue treatment if the results are not prevalent immediately.

Purpose:

The purpose of this case report is to discuss differential diagnosis for an adolescent swimmer with chronic shoulder pain. This patient case was selected due to the high prevalence of shoulder pain in competitive swimmers and lack of evidence indicating cervical spine as a potential pain generator in this patient population. The evidence on “Swimmer’s Shoulder” is abundant, but many studies lack inclusion of cervical spine involvement in the differential diagnosis, therefore, may lead to a missed diagnosis and poorer patient outcomes.

History:

The patient is a 14 year old female competitive swimmer that presented to an outpatient orthopedic center with chronic right shoulder pain. She reported pain and a locking sensation in her right shoulder about one hour into practice which worsened as practice progressed. The patient described her pain as dull midway through practice increasing to sharp by the end of practice, but quickly resolved or significantly reduced when she stopped swimming. The patient also reported this pain was primarily associated with two different strokes, the butterfly or front crawl. She denied pain or difficulty with all other activities.

The patient reported this pain pattern started about 1 year ago with no traumatic event. She reported her pain had a fluctuated course over the last year with two other physical therapy episodes as well as a bout of chiropractic care with neither providing full relief. The patient reported her first physical therapy episode of care was about 11 months ago, her second physical therapy episode was around 7 months ago, and her chiropractic care was around 2-3 months ago. The patient also reported seeing an orthopedic physician about 7 months ago. According to the patient, the previous physical therapy treatments included multiple upper extremity exercises that focused on rotator cuff and periscapular strengthening. The patient reported the chiropractor focused more on her back and performed some spinal manipulations. Information on the patient's first physical therapy episode and chiropractic care could not be obtained. However, the orthopedic physician's findings are summarized in Table 2 and the physical therapist's findings from the second episode of physical therapy are summarized in Table 3.

Table 2. Orthopedic Physician Summary of Findings.

Inspection	No erythema, edema, or gross deformity. Mild scapular dyskinesia bilaterally
Palpation	Tender to palpation over the acromioclavicular joint, biceps tendon, and coracoid process
ROM	>150 degrees of forward flexion and abduction. 70+ degrees of external and internal rotation. 60 degrees of shoulder extension
Strength	Grossly 5/5 shoulder abduction, internal rotation, external rotation, elbow flexion and extension
Sensation	Grossly intact C5-T1 dermatomes bilaterally
Special Test	Negative tests include: Neer's, Hawkins-Kennedy, empty can, Dynamic labral shear, speed's, sulcus sign, apprehension and relocation, and Spurling's. Abnormal tests include: O'Brien's caused pain in anterior shoulder, Cross body adduction also caused pain.

The orthopedic physician ordered radiographs and performed an informal diagnostic ultrasound, which all occurred about 7 months prior to the most recent physical therapy episode of care. The radiographs showed no evidence of acute fractures or dislocations and demonstrated well-preserved joint space. The diagnostic ultrasound examination found no evidence of supraspinatus or biceps tendinopathy, however, presence of mild thickening of the tenosynovium without any hyperemia was observed. Also noted was moderately diffuse hyperemia deep to her coracoid.

Shortly after this visit with the physician, the patient saw an outpatient orthopedic physical therapist. At that time, the therapist also noted aching/nagging pain with the front crawl and butterfly strokes, with additional evaluation findings provided in Table 3. The patient was seen for about 3 months duration with a subjective report of 80% improvement. The patient was then discharged to her home exercise program.

Table 3. Physical Therapy Findings 7 months prior	
Palpation	Tender to palpation over the biceps tendon and posterior rotator cuff
ROM	185 degrees of forward flexion. 95 degrees of external rotation. 60 degrees internal rotation with pain.
Strength	Shoulder external rotation = 4-/5 with pain, scaption 4/5 with winging, supination 4-/5 with pain.
Special Test	Negative Tests Include: External Rotation lag sign, Belly press sign Positive Test Include: Hawkins-Kennedy, O'Brian, Speeds

Initial Examination:

Four months after the completion of the second episode of physical therapy, the patient presented to our outpatient orthopedic clinic with chronic right shoulder pain of about one year duration with the primary complaint of pain and dysfunction during swimming practice. As stated above, the patient denied pain at the beginning of swim practice, but reported a "locking" sensation about 1 hour into practice. The patient reported this pain had worsening over the past couple of months, and reported her verbal pain rating as 2/10 at rest during the initial visit and 6/10 at its worst. Ice, ibuprofen, and discontinuation of swimming were reported as the easing factors. Aggravating factors included only swimming, and the patient denied pain with all other activities. The patient denied recent fever/chills, bowel or bladder changes, unexplained weight loss, night pain, or other medical issues.

The patient reported she had been involved in swimming activities for 7-8 years and was participating in swim practices 1-2 times per day for up to 4 hours a day at least 5 days a week. She reported increased pain with the front crawl and breaststroke. Her goals were to decrease pain and improve the amount of time prior to onset of pain during practice. She also had a goal to participate in long distance races during an opening swim meet in 3 weeks. The patient lived at home with supportive parents and her mother was present during all visits.

Table 4. Physical Therapy Evaluation Findings of Current Episode of Care	
Inspection	Forward head. Rounded shoulders. No edema or gross deformity present. Slight downward rotation and protraction of the right scapula.
Palpation	Tender to palpation and increased muscular tightness of the right upper trapezius, scalenes, levator scapulae, and supraspinatus.
ROM	Right Shoulder: > 180 degrees of flexion and abduction, 90 degrees of external rotation, 65 degrees of internal rotation. 60 degrees of extension. Gross cervical spine screen indicates full ROM in all directions.

Strength	Right Shoulder: Flexion 4/5, Abduction 4/5, external rotation 4/5, lower trapezius 4-/5, rhomboids 4-/5. Left shoulder was grossly 5/5, except for lower trapezius 4/5 and rhomboids 4+/5. Cervical Spine: The patient was unable to maintain a chin tuck when lifting her head off of the mat table in supine.
Sensation	Grossly intact bilateral upper extremities
Special Test	Positive right shoulder tests include: Hawkins-Kennedy, Empty can test Accessory joint motion indicates hypermobility grade 4 at C4, C5, C6. Standing with upper extremities in pivot prone position, the patient demonstrated slight right scapular winging with moderate over pressure. Negative right shoulder tests include: External rotation lag sign, O'Brien's Active Compression test, Speed's test, Sulcus signs, and no evidence of a painful arch sign

The initial evaluation objective values are summarized in Table 4. Upon observation, the patient appeared to be an active, healthy 14 year old. During the initial inspection, the patient presented with no gross abnormalities or edema in her right shoulder, but demonstrated poor resting posture. During the subjective portion, the patient sat at the edge of the mat table with a rounded shoulders, forward head posture. When we addressed this later in the session, the mother reported she had noticed this posture often. The forward head, rounded shoulders places the upper cervical spine in extension and the lower cervical spine in flexion along with protraction and downward rotation of the scapula. It has been found that every inch of forward head posture increases the weight of the head by about 10 pounds which requires increased activation of the cervical musculature.[4] This posture has also been associated with shortening of the upper trapezius, splenius capitis, semispinalis capitis and cervicis, cervical erector spinae and levator scapulae. The rounded shoulder posture may result in increased thoracic kyphosis, scapular downward rotation, and scapular protraction and therefore, encourage shortening of the pectoralis minor and lengthening of the middle trapezius. Muscular length alterations and increased cervical muscle activation as a result of this posture may place swimmers at higher risk for shoulder injuries.[14]

Along with poor resting posture, we observed abnormalities when the patient was asked to stand with "good posture". A posterior view of the upper quadrant demonstrated downward rotation and protraction of her right scapula by comparing bilateral scapula in relation to her spine. Research done by Smith et al., indicates that normal resting position of the scapula which measures the medial border of the scapula to the spinous process should be about 2 inches.[17] On an estimated measurement, our patient's left scapula was about 2 inches from her spinous processes, but her right scapula appeared to be around 2.5 inches from the spinous processes. With optimal positioning, the scapula sits at a 5 degree upward rotation which creates a slight shelf for the humeral head to rest on and therefore, decreases the amount of muscle force required to hold the humeral head into the glenoid cavity. With a loss of this upward rotation, more muscle activation is required by the supraspinatus and increased stresses are placed on this muscle over time.

The patient also presented with slight tenderness to palpation over her right upper quarter compared to her left side. We noted increased muscular tightness over the right upper trapezius, scalenes, levator scapulae, and supraspinatus muscles. The patient was short sitting on the mat table during palpation.

Range of motion (ROM) was performed with a goniometer and the patient in supine or prone positioning. The patient presented with full shoulder flexion, extension, abduction and external rotation. Normal shoulder internal rotation is 0-70 degrees and our patient presented with only a slight reduction as she achieves 65 degrees. A gross screen of the cervical spine indicated no issues in any direction.

Strength was tested by manual muscle test and is scored on a 0-5/5 scale. Our patient's strength was no lower than 4-/5 which indicates the patient was able to perform full range of motion against gravity and hold against moderate to strong over pressure. Our patient scored the lowest on periscapular strength, but in general appeared to have adequate strength.

Special tests included Hawkins-Kennedy, Empty Can Test, External Rotation Lag Sign, O'Brien's Active Compression test, Speed's Test, Sulcus Sign, and Painful Arch Sign. The Sensitivity and Specificity for each test, if available, are provided in Table 5. Positive special tests included the Hawkins-Kennedy and Empty Can Test. The Hawkins-Kennedy Impingement Test was performed with the patient in short sitting. The patient's arm was flexed to 90 degrees with the elbow bent to 90 degrees. The arm was then internally rotated with horizontal adduction. Pain during internal rotation indicates a positive tests. The empty can test was performed by positioning the patient in 90 degrees of flexion in the scapular plane with full internal rotation. The assessor then applied a downward pressure on the distal forearm with the patient resisting. She presented with pain and weakness indicating a positive test. Negative special tests include External Rotation Lag Sign, O'Brien's Active Compression Test, Speed's Test, Sulcus Sign, and Painful Arch Sign.

Table 5

Special Test	Sensitivity	Specificity	Reason
Hawkins-Kennedy	.88	.43	Impingement
Empty Can Test	Pain: 0.63 Weak: 0.77 Both: 0.86	0.55 0.68 0.5	Supraspinatus tendon tears
External Rotation Lag Sign	.56	.98	Infraspinatus & teres minor tears
O'Brien's Active Compression Test	.85	.41	Superior Labrum Anterior Posterior (SLAP) lesions
Speed's Test	.78	.37	Biceps Brachii Pathology
Sulcus Sign	N/A		Hypermobility
Painful Arch sign	N/A		Impingement & Rotator cuff pathology

Research found from Dutton pages 629/638 [5]

Accessory joint motion was also assessed and hypermobility grade 4 was found at cervical spine segments C4, C5, and C6. Posterior to anterior spinous process cervical glides were performed with the patient in supine to determine accessory cervical joint motion. Whitman et al. sought out the opinion of 466 manual physical therapists on the validity of a spinal segmental motion assessment.[20] The definition of validity is, "degree to which a useful (meaningful) interpretation can be inferred from a measurement".[12] The results of this study indicated that 66% of respondents believed that passive accessory intervertebral motion is a valid assessment of quantity of segmental motion. They also found that 98% of manual physical therapists reported their findings on segmental motion tests played a part in their treatment decisions and plan of care.[20]

Scapular winging was found by positioning the patient's upper extremity in a pivot prone position in standing, as shown in Figure 1, and then providing overpressure to the upper extremity from posterior while examining the scapula. Manning et al. describes scapular winging as being, "characterized by a failure of the dynamic stabilizing structures that keep the scapula anchored to the chest wall, leading to a prominence of the scapula".[9] Our patient had a very slight display of right scapular winging in which the inferior angle tipped away from the thoracic cage with over pressure when compared to the left scapula.

Figure 1: Standing Pivot Prone

Clinical Impression:

Additional information that was requested from the patient after initial evaluation was breathing technique with prone swimming strokes. The patient indicated that she always breathed to her right side during the front crawl.

After reflecting on the findings from the initial evaluation, our top three differential diagnoses included the following: 1) Cervical spine weakness and hypermobility with additional factors of unilateral breathing and abnormal neck and shoulder muscle tension 2) subacromial impingement due to repetitive movement of swimming 3) scapular dyskinesia and weakness causing less favorable scapular positioning during swimming strokes.

Differential Diagnosis #1) Cervical Spine Weakness and Hypermobility. Unilateral breathing and abnormal cervical and glenohumeral muscle tension and activation may also be contributing factors.

With this patient's case, we not only had to consider her history, examination findings, and objective measures, we also considered her other healthcare interventions. As she had not had full relief following her two other bouts of physical therapy, we were challenged to provide new and effective interventions that were different than prior interventions to instill trust and provide relief to our patient. With the other therapy bouts, the patient reported trialing rotator cuff and periscapular strengthening with some success, but did not resolve all of her symptoms. Thus, we placed less emphasis on the positive Hawkins-Kennedy test, Empty can test, and evidence of scapular winging. However, we felt strongly that the cervical spine hypermobility, deep cervical flexor weakness, increased tightness of right cervical musculature, and unilateral breathing patterns played contributing roles in the cause of her right shoulder pain. Therefore, we chose to begin with cervical spine strengthening as our primary intervention. Possible mechanisms, factors to consider, research, and clinical reasoning are described next.

Firstly, cervical spine hypermobility grade 4 was found at C4, C5, and C6 when assessing cervical spine assessory motion. Grade 4 hypermobility is considered slight hypermobility with indications to strengthen muscles surrounding the joint to promote stability. Within the body, there are both passive and active methods of stability. Passive stability is provided by ligaments, joint capsules, boney structures, and cartilaginous structures. Active stability comes from muscles and tendons of the body. With hypermobility, the structures providing passive stability are not as effective, and therefore, the patient must rely on the active structures, such as muscles, to provide stability. However, our patient demonstrated longus colli and capitis muscle weakness as the patient had difficulty lifting her head off the mat table in supine while maintaining a chin tuck. Therefore, when passive stability is decreased and active stability is not optimal, dysfunction may occur.

Secondly, increased muscular tension was found through palpation in the right upper quarter. There are multiple muscles of the upper quarter that attach to or near the cervical vertebra. These muscles include upper trapezius, splenius capitis and cervicis, semispinalis cervicis and capitis, levator scapulae, rectus capitis posterior major and minor, obliquus capitis superior and inferior, sternocleidomastoid, anterior/middle/posterior scalenes, longus colli, and longus capitis. Our patient demonstrated upper trapezius, levator scapulae, and scalenes tightness on the right. Some possible mechanisms that could lead to this increased muscular tightness include chronic postures, overuse, abnormal muscle pattern activation, and unilateral breathing techniques when swimming.

Breathing unilaterally results in unequal work distribution on many cervical muscles when swimming in prone positions. Our patient reported breathing solely to her right side when performing the front stroke. Therefore, muscles that are activated to rotate the head to the right had much higher demands and many more repetitive contractions when our patient was swimming compared to the muscles that would rotate her head left. In order to rotate the head to the right, activation of the following muscles on the right side include splenius capitis and cervicis, longissimus capitis, rectus capitis posterior major, and obliquus capitis inferior. Activation of the following muscles on the left side for right rotation include sternocleidomastoid, semispinalis capitis, and semispinalis cervicis. Due to the prone positioning, the longus colli and capitis should also be activated to properly position the head in a neutral cervical spine orientation to take a breath. However, our patient presented with weakness of these two muscles which may have positioned the cervical spine into more flexion during swimming practice, especially as the patient fatigues. Normal respiration rate at rest is anywhere from 12-20 breaths per minute. During exercise, respiration rate can increase up to 40-50 breaths per minute. Therefore, if the patient is swimming an average of 120 minutes per practice once a day with 45 breaths per minute, she would have cervical rotation to the right on average of 5,400 times per practice. With this very large uneven distribution of muscle forces our patient may have been experiencing, we educated on the importance of bilateral breathing and encouraged her to try practicing a three stroke pattern with alternating sides of breathing.

Lastly, unilateral breathing has been found to lead to asymmetric upper extremity coordination and changes in stroke technique.[2] Coordination asymmetries were found in swimmers with unilateral breathing patterns and were attributed to a discontinuity in the stroke during the breath.[2] Coordination between the upper extremities and cervical rotators are key in determining the most efficient timing of the breath. The optimal breath should start as the ipsilateral upper extremity is in full extension and be completely finished with the head back in neutral by the time the ipsilateral hand enters the water. Following the breath intake, the swimmer should quickly turn their head back into the water prior to their ipsilateral hand passing their ear for ideal breathing technique. Research has found that less-expert swimmers typically have longer inhalation and demonstrate a greater body roll due to a head turn required for breathing.[2] A longer inhalation or breathing late in the stroke has been linked to decreased speed and may result in poor coordination of the upper extremities which commonly presents as the contralateral arm pressing into the water while the swimmer is breathing instead of assisting with propulsion.[18] As a result of this decreased coordination, higher demands are placed on the ipsilateral breathing arm to propel the swimmer forward.

Other breathing errors that may occur are increased active lateral flexion with rotation as the swimmer is trying to lift their head out of the water to breath or solely increased rotation in which the swimmer looks too far over their shoulder which negatively increases their body roll.[18] The most efficient amount of cervical rotation is demonstrated by one goggle out of the water and the other goggle in the water while breathing.[18] When patients are demonstrating both goggles out of the water while breathing, they have excessive body roll due to their head position which can influence the position of the hand upon entry of the water, and therefore, negatively affect the hand's potential to develop propulsive forces. Along with body roll, an increase in cervical rotation or an increase in lateral flexion during the breath will place higher muscular demands on the cervical rotators and extensors which may fatigue and cause pathology.

Along with breathing errors and coordination asymmetries, swimmers typically breathe towards their dominant arm. Therefore, the arm ipsilateral to breathing plays the predominant role in propulsion and control of the swimming rhythm.[1] Therefore, higher muscular demands and increased stress are placed on this upper extremity. Our patient presented with right-sided shoulder pain and she was unilaterally breathing to the right side. Therefore, her right shoulder pain could have been a result of increased stresses and high propulsion forces of the right upper extremity due to her breathing pattern and possible coordination asymmetries.

Furthermore, a combination of factors from the cervical spine may have been contributing to our patient's shoulder pain. Cervical spine weakness and abnormal upper quarter muscle tension could have resulted in right glenohumeral dysfunction. Breathing technique may also have affected the cervical spine and glenohumeral joint. Allard et al. showed that subjects with unilateral breathing patterns took breaths towards the dominant arm, and therefore, that upper extremity became more coordinated and played a larger role in propulsion.[1] Breathing patterns also alter the amount of body roll and pull phases in less expert swimmers and may result in unnecessary cervical muscle activation due to errors in breathing technique. Appropriate cervical spine strength and muscle tension, stroke technique, body rolling, and breathing technique are essential to decrease upper extremity coordination asymmetries, equalize propulsion demands, and decrease risk for injury.

Although the effects of unilateral breathing have been studied, there is lack of research studying the interactions between the cervical spine and its possible effects on the shoulder joint in swimmers. There was also a lack of evidence discussing the cervical spine as a potential pain generator in these patients which may lead to a missed diagnosis or poorer patient outcomes. More research on the relationships of the cervical spine and shoulder pain in swimming athletes is needed.

Differential Diagnosis #2) Subacromial Impingement

Subacromial impingement occurs when the contents between the inferior portion of the acromion and the superior portion of the humeral head get compressed as the subacromial space decreases. These contents include subacromial bursa, long head of the biceps, and the supraspinatus tendon. Internal subacromial impingement has more recently been described and occurs when the posterior aspect of the greater tuberosity of the humerus comes into contact with the posterosuperior glenoid. Typically, overhead athletes suffer from internal subacromial impingement, especially if there is anterior laxity and posterior tightness around the glenohumeral joint as this increases the likelihood that the humeral head will translate anteriorly and place the supraspinatus and infraspinatus in a more vulnerable position.

Research done in swimmers with impingement syndrome has shown alterations in swimming strokes and muscle activity including anterior and middle deltoid, middle trapezius, serratus anterior, and rhomboids.[3] Front stroke swimmers with impingement symptoms showed a decrease in anterior and middle deltoid activation which resulted in a more lateral hand entry into the water as there was a reduction in the amount of shoulder flexion. Painful swimmers also presented with an early hand exit from the water, possibly to avoid painful internal rotation. During the pull through phase, an increased in the recruitment of rhomboids along with a decrease in serratus anterior was found which may result in decreased scapular upward rotation and protraction which places the shoulder at higher risk for repetitive trauma.[3]

Along with abnormal muscle activation in the pull through phase, the amount of time spent in this phase has been found to increase when non-expert swimmers breathe to that side, which places that upper extremity at an increased risk for impingement.[7] During the pull phase, the upper extremity is in a range starting at equal to or greater than 180 degrees and ends at 90 degrees of shoulder flexion. Along with end range shoulder flexion, internal rotation is also required which may predispose the swimmer's ipsilateral arm of breathing to more pathology as that upper extremity is in a vulnerable position for increased time. During the initial portion of the phase, the hand is entering the water and the swimmer reaches out for a full stroke with near maximum forward shoulder flexion. Upon hand entry, the water creates a strong upward force which may elevate the upper extremity to full or past active shoulder flexion. Therefore, the swimmer is at a very high risk of subacromial impingement during this portion of the stroke as the force of the water elevates the upper extremity and compresses the contents in the subacromial space.[7] If the swimmer is solely breathing to one side, that upper extremity is at a higher risk for injury, therefore, bilateral breathing is promoted to reduce the risk of shoulder impingement.[1]

Factors that can facilitate subacromial impingement are tight pectoralis minor muscle, scapular dyskinesis, rotator cuff insufficiencies, and glenohumeral laxity. The repetitive motion of swimming can lead to irritation and constant microtrauma to the supraspinatus tendon and cause pain and further dysfunction. With the repetitive nature and extreme positions of the upper extremity that are required while swimming, impingement syndrome is a very likely diagnosis for our patient. However, periscapular and rotator cuff strengthening had been previously attempted with limited success with prior therapy bouts. The diagnostic ultrasound also did not show findings consistent with impingement syndrome. Therefore, we were challenged to think critically about the kinetic chain and other factors that may be contributing to her shoulder pain, including the cervical spine. This case may challenge clinicians to continue differential diagnosis and critical thinking when interventions are unsuccessful.

Differential Diagnosis #3) Scapular Dyskinesia:

During the initial examination, scapular winging was present as well as abnormal right scapular position at rest. Scapular winging is defined as a prominence of the medial border of the scapula or an anterior tilt.[8] Zlupko et al. reported that "visual alterations in scapula position and motion patterns has been termed scapular dyskinesis".[21] Our patient presented with both a prominence of the medial border of the scapula upon manual force in a standing pivot prone position as well as visual alterations in the position of the scapula at rest as the patient's scapula was slightly protracted.

Scapular winging could indicate weakness or abnormal activation in the serratus anterior, trapezius, and rhomboid major and minor as these muscles do majority of the work to stabilize the scapula. An anterior tilt could be present due to shortened pectoralis minor or short head of the biceps brachii muscle as both of these muscles attach to the coracoid process and assist in anteriorly tilting the scapula. Normal movement of the scapula is essential for normal shoulder function because the scapula and humerus work in a one to two ratio in order to gain full shoulder range of motion of 180 degrees. This means that 60 degrees of that total 180 degrees of motion comes from movement of the scapula and the remaining 120 degrees comes from movement of the humerus. Even though our patient had full right shoulder range of motion, the quality of that motion may have been compromised when swimming, especially towards the end of practices as the muscles fatigue.

A research study performed on competitive swimmers found that the prevalence of scapular dyskinesia increases throughout training sessions.[8] This study assessed scapular dyskinesia on twenty competitive swimmers during training sessions and results indicated that scapular dyskinesia was observed in 30% at the beginning of training, 70% an hour later, and 80% upon the end of the training session.[8] Our patient presented with symptoms appearing about 1 hour into practice and therefore, one could make a probable argument that her symptoms appeared as she fatigued, and therefore, scapular dyskinesia could have been a contributing cause of her shoulder pain.

Intervention and Outcome:

The patient was seen in physical therapy for this episode of care for 8 visits over 4 weeks with 2 visits per week. The interventions included deep cervical flexor strengthening (Figure 2), upper thoracic mobilizations, core strengthening and endurance, myofascial decompression to the right latissimus dorsi (Figure 3), upper extremity stretching on a foam roll (Figure 4), and education on posture and bilateral breathing. Most notably, deep cervical flexor strengthening was performed in supine with the patient lifting her head off the mat table and maintaining a chin tuck. During the first few sessions, the patient had difficulty maintaining the chin tuck while lifting her head, but was able to perform this task proficiently by the final visit.

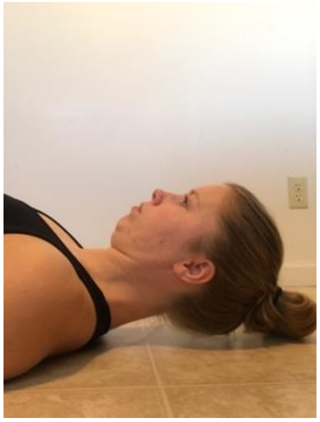

Figure 2

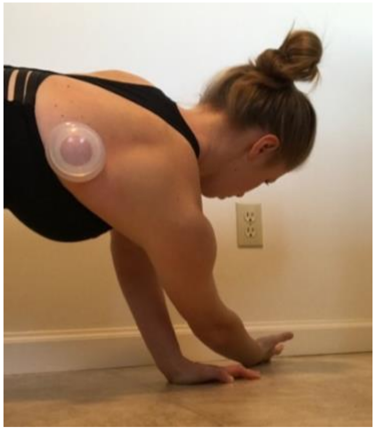

Figure 3

Figure 4

During the first visit, an initial evaluation was performed and cervical spine strengthening was initiated. The patient was also educated on posture and bilateral breathing and instructed in a home exercise program (HEP) that focused on cervical spine strengthening. Upper thoracic spine mobilization was added during the 3rd visit. Core strengthening was initiated during the 4th visit.

Myofascial decompression to the right latissimus dorsi was performed during the 5th visit. Upper extremity stretching over foam roll was added during the 6th visit. The patient's pain was monitored through a subjective report each visit. By the 3rd visit, the patient had reported less pain with swimming. During the 4th visit, the patient reported being able to swim about an hour and a half without pain and no sensations of locking. By the 5th visit, the patient was able to swim full two hour practices without pain. During the 7th visit, the patient reported dropping time in a few events. At the final visit, the patient reported 100% relief of her symptoms. Throughout her episode of care, the patient continued swimming her normal practice schedule and participated in one swim meet.

Discussion:

There are many plausible orthopedic diagnoses in swimmers with shoulder pain. With a high likelihood of impingement and scapular dyskinesia in overhead athletes, clinicians may begin treating these pathologies without examining the cervical spine. However, this patient is a good candidate for this case study because it provides an example of cervical spine involvement in a swimmer with chronic shoulder pain. Throughout her care, we did not prescribe any rotator cuff or periscapular strengthening, and yet, the patient had total relief of her chronic right shoulder pain. We attribute her success mostly to the cervical spine strengthening and bilateral breathing patterns. Therefore, her case emphasizes the importance of observing the kinetic chain, complexity of the shoulder joint, and possibility of cervical spine involvement in patients with shoulder pain. This case may challenge clinicians to examine not only the shoulder and scapula, but also perform a more in depth cervical spine exam in patients with chronic shoulder pain.

Many studies on swimming athletes were reviewed, but the majority do not mention any consideration of the cervical spine. Therefore, this case makes a novel contribution as it demonstrates healing in a patient with chronic shoulder pain when focusing on treating the cervical spine. More research is needed on how dysfunction in the cervical spine could affect the glenohumeral joint and produce shoulder pain in swimming athletes.

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